

REMARKS

Claims 1 - 3 originally filed in the application have been rejected. Claims 1, 2 and 3 have been amended and claims 1 - 3 remain in the application.

Claims 2 and 3 have been objected to on the grounds that they refer to "The process of claim 1" and should instead refer to "The clad tube of claim 1". Claims 2 and 3 have been amended accordingly and the objection should be overcome.

Claims 1 - 3 have been rejected under 35 U.S.C. 102(b) as being anticipated by, or in the alternative, under 35 U.S.C. 103(a) as obvious over Sherman (U.S. Patent 5,928,799) on the following grounds.

Sherman is cited as disclosing forming a tube by depositing a first layer of pure rhenium or rhenium alloy on a mandrel by processes including electroplating (e.g. see column 4, lines 32-52) and then applying a second layer, such as niobium, over the first layer (e.g. see column 5, lines 30-36). Sherman is cited as showing that it is understood that the rhenium layer on the mandrel may be further finished before applying the niobium layer (e.g. see column 7, lines 19-20). A specific combination of a rhenium deposit covered with niobium deposit is cited as shown in Example 3.

Regarding the intended use limitation "for nuclear fuel" (e.g. claim 1, line 1), it is stated that a recitation of the intended use of the claimed invention must result in a structural difference between the claimed invention and the prior art in order to patentably distinguish the claimed invention from the prior art. It is stated that if the prior art structure is

**ATTORNEY DOCKET CASE 7077**

capable of performing the intended use, then it meets the claim. In addition, the recitation of "for nuclear fuel" has not been given patentable weight because the recitation occurs in the preamble.

It is stated that the alternative use of electroplating methods to produce the layered article of Sherman is clearly taught by Sherman (e.g. see column 4, lines 43-52) and therefore electroplating would be an obvious alternative process to one of ordinary skill in the art for producing the products of Sherman.

The rejection is duly noted, but the inventors respectfully traverse.

Claim 1 has been amended to clarify that the niobium alloy stock contains zirconium, that the deposition of the niobium alloy over the rhenium is done while creating an atomic level bonded interface, and that the formed clad tube is for nuclear fuel.

**Regarding the 102 and 103 rejections,** the following comments are offered.

A portion of the rejection is based on the statement that "If the prior art structure is capable of performing the intended use, then it meets the claim."

The cited art of Sherman is not capable of performing the intended use as nuclear fuel cladding. The niobium outer layer (of Sherman's example 3) will pit and fail due to corrosion in a liquid metal coolant such as lithium (DeVan, et al. 1984). "If oxygen in niobium exceeds ~400 ppm, rapid intergranular and/or transgranular attack by lithium occurs at temperatures from 300 to 1200°C." (DeVan, et al. 1984) Addition of zirconium to "tie up" the contaminant oxygen significantly improves the corrosion threshold. Therefore, a niobium alloy (containing zirconium) is necessary for such a nuclear reactor application.

Furthermore, while Sherman claims a corrosion resistant interior layer fabricated of rhenium he claims only that the outer

**ATTORNEY DOCKET CASE 7077**

layer is structural. Sherman lists "niobium" metal as a possible outer layer, but he does not list "niobium alloys" or any niobium alloy as an outer layer (see Col. 2, line 46 to Col. 3, line 3; Col. 5, lines 32 to 36; example 3; and claim 4 of Sherman). He specifically states that "the high strength layer" is not "exposed to the corrosive and erosive gas environment" (Col. 5, lines 24 to 29). When a liquid metal coolant is used in a nuclear reactor, the exterior of the cladding is exposed to a potentially corrosive environment. Thus, Sherman's tubing design is unsuitable for a nuclear reactor cladding application.

The alloy content, grain structure, and trace impurities of an article fabricated by the pending product-by-process claim are different from that fabricated by the embodiment of Example 3 of Sherman.

Sherman's preferred method of fabricating the tubing, chemical vapor deposition (CVD), has not been used to fabricate an article of niobium alloy containing zirconium, which is required for a nuclear cladding application. While CVD can be used to fabricate products consisting entirely of niobium or entirely of zirconium, CVD of a niobium alloy containing a small but controlled percentage of zirconium (e.g. 1%) has to date not been reduced to practice due to limitations of the CVD technology currently available. Based on varying deposition temperatures and material vapor pressures, it is doubtful if this is feasible.

The method of fabrication of material determines the grain structure (size and shape) and trace impurities, which in turn determine the **high temperature creep behavior** of refractory metals and alloys, such as rhenium alloys, niobium, and niobium alloys (Buckman, 2000). For example, the creep behavior of rhenium depends on whether it was fabricated using powder metallurgy, electron beam melting, plasma vapor deposition, chemical vapor deposition, or electrodeposition as well as the subsequent

**ATTORNEY DOCKET CASE 7077**

processing (i.e. heat treating, working, etc.). Furthermore, refractory metal tubing produced by CVD and various electrodeposition (ED) methods (i.e. aqueous, fluoride, or chloride electrolytes) contain different impurity levels, as well as other attributes, and therefore can have different creep behavior. Rhenium and niobium produced by Sherman's preferred CVD process consists of columnar grains. Rhenium, niobium, and niobium alloys fabricated using a chloride electrolyte followed by heat treatment have equiaxed grains. In a typical reactor application of interest, the cladding must survive for years (tens of thousands of hours) at high temperatures (~ 1100°C) under loads due to internal gas pressure, etc. Therefore, excessive cladding creep can lead to cladding failure and/or decreased performance.

The entire thickness of the cladding must survive exposure to the high temperature environment, not just the interior, which the cited art claims (claim 2, column 9, lines 5 - 9). Sherman claims his device is only capable of withstanding a hot, highly corrosive environment on its interior for several hours (column 3, lines 15-19). Surviving several hours is not sufficient for a nuclear reactor application. Therefore, Sherman's tubing is not suitable for use as nuclear reactor cladding.

The design of the present application is uniquely different from Sherman's tubing and is able to operate in an environment that would destroy the tubing of Sherman (Sherman's Example 3).

While Sherman does mention electroplating as an alternative method, he does not elaborate on any specifics of the electroplating process. Until recently, electrodeposition of rhenium was done in aqueous solutions (water based) (Toenshoff, et al, 2000, and Jones, 2003). Some of these aqueous solutions could only deposit 0.005-inch thicknesses of rhenium per step and required hydrogen firings prior to additional depositions. The rhenium plating produced by this method contained cracks due to

**ATTORNEY DOCKET CASE 7077**

shrinkage (Root and Beach, 1960). Due to the discontinuities, these rhenium coatings would not prevent inert cover gas or fission product gas from leaking through and corrosively attacking the outer cladding layer. For Sherman's application as a gun barrel, propellant gas permeating through the rhenium for very brief time periods is acceptable. It is **not** acceptable for nuclear fuel cladding with a design life of many tens of thousands of hours. In addition, the presence of these cracks degrades the strength of the inner rhenium layer, which carries most of the structural load in this type of nuclear cladding.

The present application does **not** claim a bi-layered tubing consisting of an inner rhenium layer and exterior layer of niobium with 1% zirconium. Bi-layered tubing of this form predates the cited patent of Sherman. Under U.S. Department of Energy funding in the late 1980's and early 1990's, General Electric (San Jose, CA) developed a manufacturing process for a bi-layered tube for use as fuel cladding in the SP-100 Space Nuclear Reactor program (Sayre, et al., 1997). This complicated manufacturing process consisted of fabricating rhenium tubing, fabricating niobium alloy tubing, and bonding the two together using a HIP process.

Although the SP-100 program developed a bi-layered tubing manufacturing technique, cladding fabricated by the process described in the present application is unique based on its grain structure and impurity content, which affects the high temperature creep behavior and strength of the tubing. During SP-100 tubing fabrication process, rhenium was formed and drawn multiple times with intermediate anneals (heat treatments). The work imparted into the rhenium during the forming and drawing steps resulted in "extraordinary grain growth" (Sayer, 1994) (i.e. larger grains). Since tubing fabricated using the process in the present application does **not** require forming or drawing, grain growth should not be excessive during any heat treating process and

**ATTORNEY DOCKET CASE 7077**

during operation at high temperature.

**In summary,** the applicants submit that the present application is patentably distinct from Sherman on the following grounds. Articles fabricated based on Sherman's patent cannot function as nuclear fuel cladding. The method of production is critical to an article functioning as nuclear fuel cladding due to corrosion properties, creep properties due to grain structure and impurity level, and the required continuity of the inner layer for corrosion resistance and gas containment. The requirement for a niobium alloy outer layer (instead of niobium metal) makes the product in the present application distinct from Example 3 of Sherman. Although electroplating is mentioned by Sherman, the typical aqueous electroplating of rhenium produces an unacceptable cracked inner rhenium layer. Articles produced using the claimed chloride electroplating produce a continuous pressure tight internal layer, which is required for a nuclear reactor cladding application.

The references indicated in the text above are listed in greater detail below.

In view of the above amendments and remarks, it is submitted that the rejection is overcome and it is respectfully requested that a notice of allowance issue in due course.

Respectfully submitted,

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**ATTORNEY DOCKET CASE 7077**

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